
5 FIELD OPERATIONS

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CHAPTER FIVE:

FIELD OPERATIONS

The production, transportation, placement, and curing of QC/QA superstructure concrete is achieved in many different acceptable ways. Because each step in the process is critical and may affect the quality of the final product, it is important to understand the proper procedures for each. This chapter explains the common techniques used for each of these steps.

CONCRETE PLANTS

Each concrete plant is required to be inspected annually by INDOT in accordance with ITM 405. All plants basically have similar operations but vary in the types of components and amount of automation. Their function is to proportion the various components in the exact quantities which will make the specified concrete. The two most common types of concrete plants are:

1. Ready-Mix Plants
2. Central Mix Plants

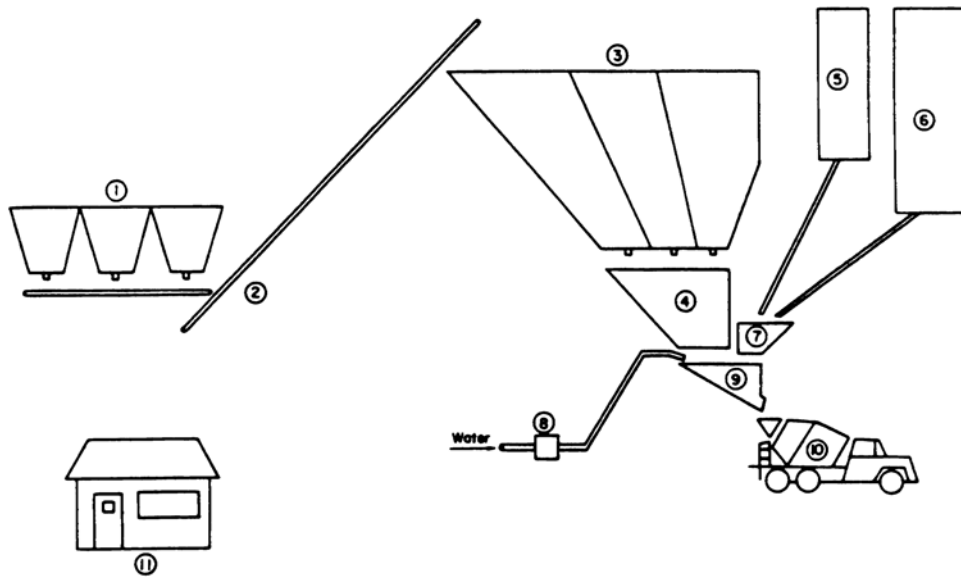
Ready-Mix Plants

Ready-mix plants are the most commonly used plants by the industry. Their function is to proportion the required components to make the desired batch of concrete. After all of the components have been discharged into the truck, the truck's mixer drum revolves and blends the components until delivery to the site of work.

Central Mix Plants

Central mix plants are normally mobile units that are located at large quantity work sites; however, more and more of these type plants are being placed at permanent locations that produce large quantities of concrete. The function of a central mix plant is very similar to a ready-mix plant with one major addition. After central plants proportion the components, a high speed, large volume mixer mixes the concrete. The freshly mixed concrete is deposited into trucks for delivery to the site of work. High volume central mix plants may have two mixer drums to increase the output capacity.

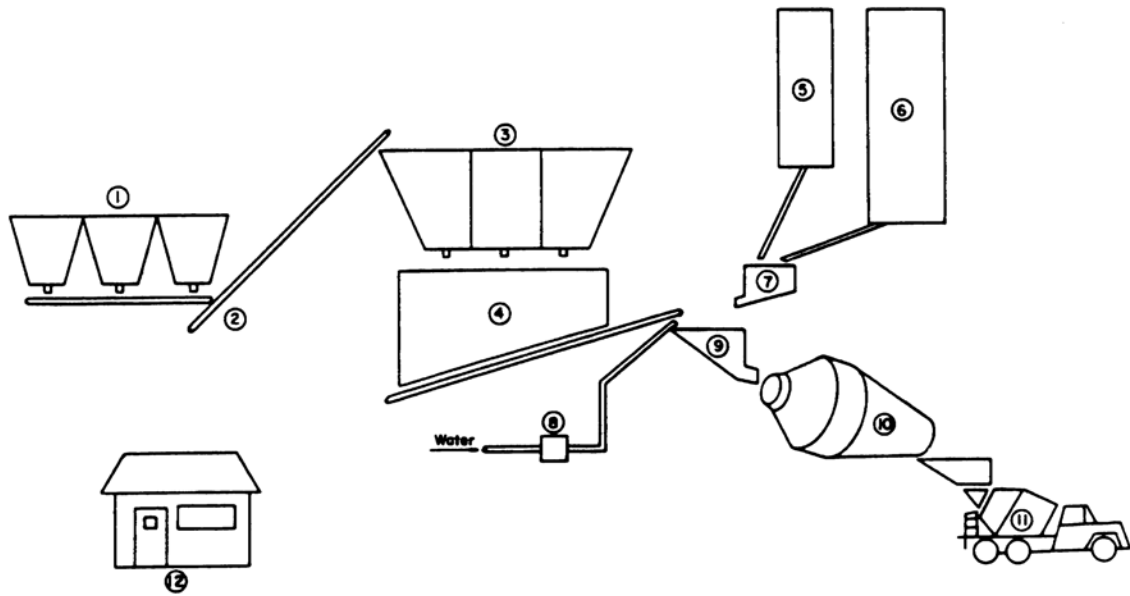
READY MIX PLANT



1. Aggregate Feeder Bins
2. Cold Feed System
3. Aggregate Proportioning Bins
4. Aggregate Weigh Hopper
5. Fly Ash Silo (OPTIONAL)
6. Cement Silo
7. Cement and Fly Ash Weigh Hopper
8. Water Meter System
9. Discharge Boot
10. Truck, Transit Mix
11. Control House

FIGURE 5.1

CENTRAL MIX PLANT



1. Aggregate Feeder Bins
2. Cold Feed System
3. Aggregate Proportioning Bins
4. Aggregate Weigh Hopper
5. Fly Ash Silo (OPTIONAL)
6. Cement Silo
7. Cement and Fly Ash Weigh Hopper
8. Water Meter System
9. Discharge Boot
10. Rotary Drum Mixer
11. Truck, Dump, Agitator, or Transit Mix
12. Control House

FIGURE 5.2

BATCHING

Batching is the process of weighing and introducing into the mixer the ingredients for a batch of concrete. INDOT requires that the minimum batch shall be 2 yd³, unless otherwise permitted. Specific requirements for the bins and scales are designated in 702.06(d) of the Standard Specifications. The ingredients that may be batched through the plant include aggregates, cement, fly ash, ground granulated blast furnace slag, water, and the admixtures.

Aggregates

Aggregates are either stockpiled at the concrete plant or unloaded directly into the aggregate feeder bins. When stockpiling aggregates, care should be taken to prevent segregation. The most common procedure for building a stockpile is by individual truck loads. The best truck-built stockpiles are those that are constructed one dump high with each dump placed against the previously dumped material. Because of the low profile of the stockpile, large particles are less likely to roll down the sloped sides of the pile and cause segregation of the aggregate. The disadvantage of truck-built stockpiles is that they require more space than other stockpiling techniques. To reduce the stockpiling area, some dumps may be restocked on top of other dumps with an endloader operating from ground level. In this case, care should be taken to place the upper lift back from the edge far enough that a long sloped face is not created that would cause segregation. The height of the stockpile cannot exceed 6 ft.

Stockpiles should be sufficiently separated to avoid contamination and placed in well drained areas to promote uniform moisture content. Washed aggregates are required to drain for a least 12 h prior to use. Longer drainage times may be required when the moisture becomes non-uniform.

Retrieving material properly from a stockpile is just as important as building the stockpile properly. The entire front face of each stockpile should be worked by a front-end loader side to side when charging the aggregate feed bins. The sides of the face should be mixed with the center of the face and the existing yard material not included in the bucket.

Either a bucket elevator or belt elevator moves the aggregate from the aggregate feed bins into the aggregate proportioning bins. The aggregates are deposited from the proportioning bins into the weigh hopper. The flow of aggregates during this transfer is controlled to measure the exact amount. The proportioning (batching) operation can range from a fully automated system to a manually controlled system using hand pulled levers. Although the fine and coarse aggregates are deposited in the same weigh hopper, each type of aggregate must be weighed separately to maintain proper proportioning. Batching is conducted so as to obtain the aggregate weights required for one batch within a tolerance of ± 2 percent. The gate on each proportioning bin must close tightly to prevent leakage of material into the weigh hopper. The aggregate in the weigh hopper is now ready to enter the mixer. The two keys to a successful aggregate operation are segregation control and accurate weighing of each component.

Cement

Cement is typically brought to the plant by bulk transport truck and is placed into a silo. The cement weighing hopper is required to be sealed and vented to preclude dusting during operation. The correct amount of cement for the batch is deposited into the weigh hopper. The accuracy of cement batching is required to be ± 1 percent of the required weight. When the correct amount of cement is in the weigh hopper, the cement is ready to be added to the mixer through a discharge chute along with the aggregates. The discharge chute cannot be suspended from the weigh hopper and shall be so arranged that the cement does not lodge in it nor leak from it.

Fly Ash and Ground Granulated Blast Furnace Slag (GGBFS)

Fly ash or GGBFS is received at the plant by bulk transport truck and is stored in a weather proof silo similar to cement. The cement and fly ash or GGBFS are weighed in the same weigh hopper. When a manual operated plant is used, both products are normally weighed and discharged separately. When an automatic batching plant is utilized, the fly ash or GGBFS may be weighed into the cement hopper in one cumulative operation with the cement always being weighed in first.

Water

Water is controlled by either volume or weight. The majority of plants use a meter system to measure the volume of water required.

The water meter system typically pumps straight into the mixer. A holding tank is sometimes added to the plant to increase production, similar to the weigh hopper for aggregate and cement. The most accurate method to add water is to monitor the water by weight. The accuracy of measuring the water is required to be ± 1 percent of the required amount. Accurate control of the quantity of water is important in maintaining proper slump and the water/cementitious ratio of the concrete.

The quality of the water used typically is not a problem. Potable water can be used without testing. If the quality of the water is not potable, the water is required to be tested in accordance with the Standard Specifications.

Admixtures

Admixtures usually are in liquid form, although paste and powder admixtures are acceptable. Powdered admixtures are measured by weight and added to the aggregates that have been batched into the weigh hopper. Liquid or paste admixtures are measured by weight or volume and are added to the water flow. Air entraining admixtures are normally added to the fine aggregate. Liquid admixtures are most commonly introduced by means of a calibrated cylinder operated by air pressure.

The accuracy of the measuring device for all of the admixtures is required to be ± 3 percent of the amount required. When admixtures are used in small quantities in proportion to the cement, mechanical dispensing equipment is required. Admixture dispensers should be checked daily since errors in dispensing admixtures, particularly overdoses, can lead to serious problems in both freshly mixed and hardened concrete.

MIXING AND TRANSPORTING

Concrete should be mixed thoroughly until it is uniform in appearance and all ingredients are evenly distributed. Mixers should not exceed their rated capacities and should be operated at approximately the speeds for which they were designed. If an increased output of concrete is needed, a larger mixer or additional mixers should be used rather than speeding up or overloading the existing mixer. Badly worn blades should be replaced immediately and hardened concrete removed from the blades daily to maintain efficient mixing action.

Concrete may be mixed completely in a stationary mixer and the mixed concrete delivered in a truck-agitator or truck-mixer; partially mixed in a stationary mixer and the mixing completed in a truck-mixer; or mixed completely in a truck-mixer. The most common techniques for superstructure concrete are mixing in a stationary mixer and delivery by truck-mixer and mixing completely in a truck-mixer. These two procedures will be discussed in this section.

Stationary Mixers

Concrete mixed in a stationary mixer and delivered to the project in a dump, agitator, or mixer truck is known as central-mixed concrete. The mixer is required to be operated within the limits of the capacity and speed of rotations designated by the manufacturer and within the following guidelines:

1. The complete mixing time shall be no less than 60 seconds. Mixing time shall be measured from the time that all of the cement and aggregate are in the drum.
2. The batch shall be so charged into the mixer that some of the water enters in advance of the cement and aggregates.
3. All required water shall be in the drum by the end of the first quarter of the specified mixing time.
4. The "mixing speed" shall be the recommended speed by the manufacturer of the plant. Typically, the mixing speed is between 14 and 20 revolutions per minute.
5. The mixer shall be equipped with an acceptable timing device which does not permit the batch to be discharged until the specified mixing time has elapsed.

Transportation of the central-mixed concrete by a truck-mixer shall be completed to the site of work and discharged within 90 minutes after the introduction of the mixing water to the cement and aggregates. Further mixing in the truck-mixer is allowed during transportation at the speed designated by the manufacturer of the equipment as the "agitating speed."

Truck-Mixers

Concrete mixed completely in a truck-mixer is known as transit-mixed concrete. The requirements for the use of truck-mixers include:

1. The number of revolutions of the drum or blades at mixing speed shall be no less than 70 nor more than 100, and not less than that recommended by the mixer manufacturer.
2. The truck-mixer shall be equipped with means by which the number of revolutions of the drum may be readily verified. The counters shall be actuated at the time of starting the mix at mixing speed.
3. Mixing operations shall begin within 30 minutes after the cement has been added to the aggregates.

4. Wash water shall not be used as a portion of the mixing water for succeeding batches.

The truck-mixer should not mix at the mixing speed beyond the required numbers of revolutions. Extended mixing at this speed will result in concrete strength loss, temperature rise, excessive loss of entrained air, and accelerated slump loss.

PUMPING

Concrete pumping has become a common technique used in bridge construction because this method allows the placement of concrete at locations not accessible to concrete trucks. However, due to the nature of the pumping process, pumping of concrete can cause the air content of concrete to be altered. These changes can be anticipated and controlled using proper production, testing, and pumping techniques. Also, coordination and cooperation between all parties involved is essential to ensure the success of the pumping operation.

Requirements

When pumping is used to convey concrete, the material shall be handled so as to minimize the change in properties of the concrete. The pumping equipment shall be mechanically sound and adequate in capacity for the proposed work. In addition, the following requirements of the Standard Specifications must be met:

1. The concrete shall not be pumped through aluminum or aluminum alloy pipe.
2. All pipes used for pumping shall be kept clean and free from coatings of hardened concrete.
3. Pump lines shall not rest directly on epoxy coated reinforcing steel.
4. The pumping equipment shall be located such that operational vibrations will not damage freshly placed concrete.
5. When placing concrete directly from a truck mounted boom, the concrete pump lines shall have a flexible end section at least 10 ft long.
6. The method of placement shall be such as to result in a steady and continuous discharge. This may require a restrictive device at or near the end of the discharge tube, laying the flexible end section horizontally, or other means.

7. For initial placement of concrete pours which are predominately vertical, the discharge end of the flexible end section shall be within 2 ft of the bottom of the pour.

Causes of Air Increase

There are two possible causes for the increase in air content. Both can occur at delivery of the concrete. The causes are:

1. Initial pressure in the line
2. Pumping in adverse weather

Initial Pressure

An increase in air content can occur when the concrete is introduced to the pump. When concrete first enters the pump line a small amount of air is mixed into the concrete. The additional air is the result of the pressure present in the pump line. This phenomenon may be unavoidable, but should be noted when sampling is scheduled. Also, this problem should be anticipated and considered in the production process.

Adverse Weather

Pumping concrete in adverse weather should be avoided. Water from rain can be added to the concrete directly or indirectly through build up in the hopper. The excess water in the concrete mix will cause an increase in the air content. If adverse weather should come unexpectedly, immediate action should be taken to protect the concrete and the hopper from the rain.

Causes of Air Loss

The causes for a decrease in air content of pumped concrete are as follows:

1. Loss of air content due to impact force
2. Bursting of air voids by vacuum
3. High pressure dissolution of voids

Loss of Air Content Due to Impact Force

The impact of the moving concrete with stationary objects results in the loss of air. Thus, the voids are broken by mechanical action. This action can be responsible for losses of between 20 and 40 percent of the initial air content. Impact can occur on the walls and joints of the pump lines as well as the impact of the concrete on the deck.

In general, losses from the pump can be anticipated and taken into account in the initial air content of the concrete. However, control of air loss due to impact with the deck is a matter of construction technique. In order to control this type of air loss, the fall distance from the end of the pump line should be minimized. A good fall distance is considered less than 2 ft. Also, to reduce the speed at which the concrete is deposited on the deck, various attachments can be added to the end of the line. These attachments include reducers, elbows and hoses.

Bursting of Air Voids by Vacuum

Concrete may overcome the effects of friction while being pumped through a descending line. When this loss of friction occurs, a vacuum can be created in the line. In this condition, the internal pressure of larger air voids can cause them to burst. A significant drop in detected air content can be exhibited if this phenomenon occurs.

Steep, descending sections of the boom allow the concrete in the line to speed up and to become discontinuous. These two factors, speed and discontinuity, facilitate the development of a vacuum in the line. Thus, steep, descending sections of the line should be kept to a minimum. Also, reducers, elbows or hoses can be configured to reduce the speed at which the concrete flows and to keep the flow of concrete continuous.

Busting of air voids by vacuum can also occur if the mix has too stiff a consistency as may be indicated by a low slump. Again the mix will have the tendency to break apart, thus causing a vacuum to develop. To remedy this situation, a mix with a proper consistency for pumping should be used.

High pressure dissolution of voids

High pumping pressure causes the air voids in the concrete to become smaller or to disappear completely. These voids do not completely recover once the pressure is returned to lower levels. This mechanism effects smaller air voids more so than the larger voids. It is these small voids that are essential to the concrete's freeze-thaw durability. Thus, this method of air loss, when compared to the previous two methods, can have the most severe effect on the durability of concrete. This phenomenon occurs within the first few seconds that the concrete is under pressure. Thus, increasing the pump rate to decrease the amount of time the concrete is under pressure will not lower the amount of damage to the air void system.

One way to prevent this problem from occurring is to keep the pump pressure to a minimum. Also, if a concrete has a stiff consistency the pressure required to pump the concrete will be higher. Thus, using a concrete with a proper consistency will help prevent this type of air loss.

Controlling Air Content

Control of air content in pumped concrete primarily depends on the following items:

1. Proper production of the concrete
2. Proper testing of the air content of the concrete
3. Proper concrete pumping techniques.

Proper Production of Concrete

Concrete moves as a cylinder or slug through the pipeline system of the pump truck. The concrete is separated from the wall of the line by a layer of water which serves as a lubricant. The pump lines often contain tapered sections and elbows through which the concrete must pass. Aggregate size, aggregate gradation, water content, cement content, and admixtures all can have an effect on the pumping characteristics of concrete.

Consistency of the mix is a primary concern. If a mix has a stiff consistency, the pump will not be able to easily move the concrete and the line may become blocked. Also, stiff consistency type mixes tend to become discontinuous within the line. When this occurs, a vacuum can develop in the line which will cause the bursting of air voids. Further, high pumping pressures are required to pump a stiff mix. This may cause high pressure dissolution of voids.

Conversely, if the mix has a loose consistency as may be indicated by a high slump, the mix may segregate under the pressure of the pump. If segregation occurs, the aggregate may settle in the line and also cause the line to become blocked. Also, a high slump mix will flow too quickly through the line, causing vacuum pressure to develop. Further, quick movement through the line will increase the speed at which the concrete impacts objects. Impact with stationary objects also causes air loss in concrete. Thus, when developing a new mix design or when working with a mix with unknown pumping characteristics, a full-scale test of the mix is recommended.

In order to prevent any problems at the jobsite, the uniformity of the concrete from batch to batch is essential. Changes from batch to batch are likely to change the pumping characteristics of the concrete.

Proper Testing

In order to ensure that the concrete being delivered meets the mixture requirements, air content tests can be performed before the concrete is discharged into the pump. Although not required as a quality control test, these tests will serve to verify the initial air content and to monitor mix variability.

Many different mechanisms can cause the loss of air voids in the pumped concrete. Thus, in order to assure that the concrete being tested for air content most accurately represents the concrete that is being placed, samples must be taken on the bridge deck, directly at the end of the pump line. This concrete will best represent the changes made to the air content of the mix by the pumping process. Tests taken at the pump hopper cannot be used to represent the concrete that is placed in the bridge deck.

Sampling at the end of the pump line may be difficult due to boom or line configurations. Further, pumping pressure may cause added difficulties in sampling. Thus, it is necessary to plan ahead to assure that representative sampling can be done with minimal disruption to the pumping pressure.

Proper Pumping

Many of the losses of air in concrete can be controlled by proper pumping techniques. Keeping the pump at the lowest possible pressure helps prevent high pressure dissolution of air voids. Minimizing steep, descending sections of the pump line prevents bursting of air voids by vacuum. Keeping a proper fall distance helps to decrease the loss of air content due to impact force. A good rule of thumb is to match the pump rate to the speed at which the concrete falls through the line.

Different line configurations can also be utilized for pumping concrete. These configurations are used to build up resistance in the line and slow the descent of the concrete. The following configurations are used for this purpose:

1. Reducers
2. Elbows
3. Hose slung 90 degrees
4. Extended hose, laid horizontally

As is with any construction process, safety is a primary concern. Any attachment or series of attachments made at the end of the line must not exceed the maximum weight requirement as stipulated by the pump manufacturer.

Communication

Many individuals are involved with the production, testing, pumping, and placement of the concrete. Therefore, coordination and cooperation between the producer, the technician, the pumper, and the contractor are essential. A pre-pump meeting, which all involved parties attend, is recommended. This step will help assure that a clear line of communication is established between everyone before the pumping begins.

CURING

Curing of concrete is the maintenance of a satisfactory moisture content and temperature during some period immediately following placing and finishing. Curing has a major influence on the properties of hardened concrete such as durability, strength, water tightness, abrasion resistance, volume stability, and resistance to freezing and thawing and deicer salts. The top surface strength development of exposed slab surfaces can be reduced significantly when curing is defective.

The objectives of curing are to:

1. Prevent (or replenish) the loss of moisture from concrete
2. Maintain a favorable concrete temperature for a definite period of time.

Maintaining the moisture in concrete is critical for obtaining complete hydration of the cement. Most concrete mixtures contain sufficient water for workability and hydration of the cement; however, any appreciable loss of water by evaporation or otherwise will delay or prevent complete hydration and proper development of gel to close off the pore structure. It is important to retain the water the first few days after placement since hydration is relatively rapid during this time. When moist curing is interrupted or insufficient, the concrete will not develop to its full potential of strength, durability and impermeability. If moisture loss from the exposed surface exceeds the rate of bleeding, stresses will develop from the shrinkage, which may result in surface cracking.

Maintaining a favorable concrete temperature for a period of time is essential for obtaining the proper hydration. The hydration of the cement proceeds at a much slower rate when the concrete temperature is low. The strength of the concrete is effected as follows:

50°F -- unfavorable for the development of early strength

40°F -- early strength is greatly retarded

14°F - 32°F -- little or no strength develops

Requirements

QC/QA superstructure concrete is required to be wet cured per the Standard Specifications with some exceptions. After finishing and texturing the bridge deck, the exposed concrete surface shall receive an application of an approved evaporative retardant to protect against plastic shrinkage cracks. Reapplication of the retardant should be performed whenever the surface is disturbed, or when drying of the surface is observed. The evaporative retardant may be eliminated for concrete not containing silica fume, if the Contractor can substantiate that the evaporation rate for any exposed concrete does not exceed 0.15 lbs/ft²/h. Evaporative retardant shall be applied to the finished or textured surface of concrete containing silica fume, regardless of evaporation rate.

Evaporation Rate

The rate of water evaporation shall be determination by the procedure specified in ACI 308 (section 1.2.1) or the following equation:

$$E = [T_c^{2.5} - (r \times T_a^{2.5})] [1 + 0.4 V] \times 10^{-6}$$

where:

E = evaporation rate, lb/ft²/h

T_c = concrete temperature, °F

T_a = air temperature, °F

r = (relative humidity %) / 100

V = wind velocity, mph

Measurements of T_a , r , and V are obtained from on site readings and compared for accuracy with readings from the nearest weather station monitored by the National Climatic Data Center. T_c is determined from the concrete placed within the bridge deck.

A relatively simple procedure for determination of the rate of evaporation is the use of the chart in Figure 5.3. By drawing a line to intercept the appropriate air temperature, relative humidity, concrete temperature, and wind velocity values, in this order, the rate of evaporation can be approximated. If the chart value is close to the maximum allowable rate of evaporation specified, the equation described previously should be used for a more accurate measurement.

Example: (See Figure 5.3)

Air Temperature = 65°F
Relative Humidity = 45%
Concrete Temperature = 60°F
Wind Velocity = 20 mph

Evaporation Rate ≈ 0.11 lb/ft²/h

Example: (using formula)

$$\begin{aligned} E &= [T_c^{2.5} - (r \times T_a^{2.5})] [1 + 0.4 V] \times 10^{-6} \\ E &= [(60 \times 60 \times \sqrt{60}) - (0.45 \times 65 \times 65 \times \sqrt{65})] [1 + (0.4 \times 20)] \times 10^{-6} \\ E &= [27885 - 15328] [1 + 8] \times 10^{-6} \\ E &= 12557 \times 9 \times 10^{-6} \\ E &= 0.11 \text{ lb/ft}^2/\text{h} \end{aligned}$$

Protective Covering for Wet Curing

Concrete in bridge decks or the top surface of reinforced concrete slabs shall be wet cured continuously for at least 168 h commencing immediately after the surface is able to support the protective covering without deformation. An extended wet cure period is not required for concrete containing pozzolans.

Surfaces to be cured shall be protected by covering with cotton mats, burlap, or other satisfactory protective material that is kept continuously and thoroughly wet during the curing period. The protective covering shall be suitably anchored. Curbs, walls, handrails, copings, and other surfaces requiring a finish in accordance with 702.21 may have the covering temporarily removed for finishing, but the cover shall be restored as soon as possible

Silica Fume Modified Concrete

If the QC/QA superstructure concrete contains silica fume, an evaporation retardant is required regardless of evaporation rate and is to be applied to the exposed concrete surface immediately after finishing or texturing operations in accordance with the manufacturer's recommendation. Reapplication of the retardant should be performed whenever the surface is disturbed, or when drying of the surface is observed.

If the rate of evaporation exceeds 0.10 lbs/ft²/h, fog misting, as recommended by the silica fume manufacturer, is required to be performed after the finishing operation prior to the texturing operation. Fog misting shall not be excessive to cause water to wash the fresh concrete surface, or to stand on the surface during floating or troweling operations. Fog misting keeps the environment at the concrete surface at high humidity to protect against plastic shrinkage cracks and is not intended to facilitate finishing.

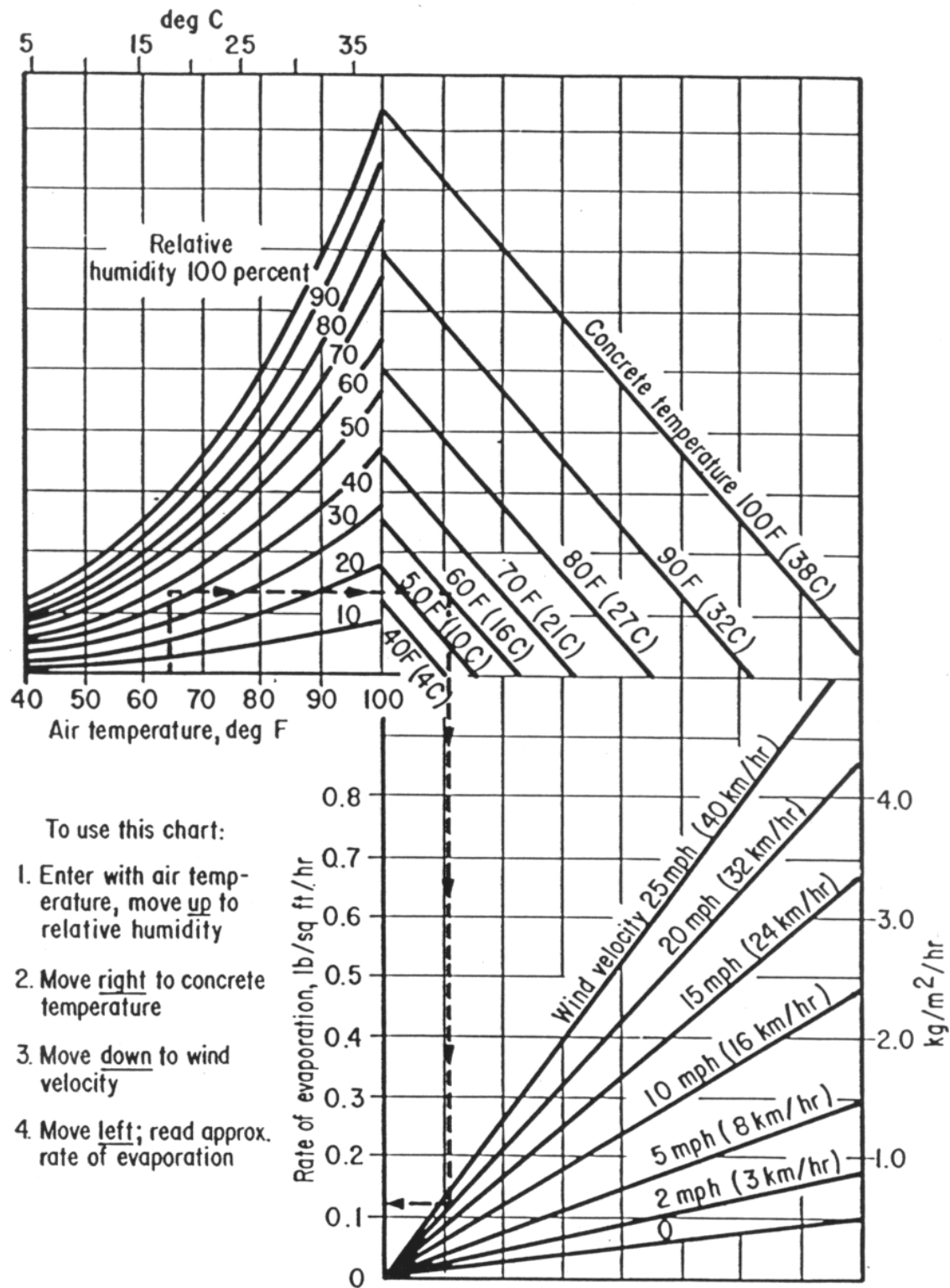


FIGURE 5.3